On Some Continuous Observations of the Rate of Dissipation of Electric Charges in the Open Air.

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During the latter part of 1902 and the early months of 1903 I resolved to take as many observations of the rates of dissipation of positive and negative electric charges as possible, and to continue them over the whole 24 hours of the day, and, when opportunity offered, over longer periods. There appeared to be little information regarding the rate of dispersion during the night hours. At about the same time that these observations were being made, Nilsson* was doing similar work at Upsala, and found a noticeable maximum value for atmospheric conductivity at about midnight.

The observations were made on the Canterbury Plains of New Zealand, at a station about 20 feet above sea-level and about five miles due west from the sea coast. The apparatus used was Elster and Geitel's† *Zerstreuungs-apparat*, and the formula of reduction used was that given by them, viz.:—

$$E = \frac{1}{t}\log\frac{V_0}{V} - \frac{n}{t'}\log\frac{V'_0}{V'}.$$

In this formula E is proportional to the conductivity of the gas surrounding the instrument—for positive or negative charges, as the case may be. The constant "n" = ratio of

$$\frac{\text{capacity without cylinder}}{\text{capacity with cylinder}}$$

was determined by me to be 0·47, as the instrument was always used, with the protecting cover. The cover was always at one height above the base of the instrument, and was set so as to be as nearly co-axial with the discharging cylinder as could be judged by eye. No attempt was made to determine the actual capacity of the condenser cylinder and protecting cover, which would be a somewhat variable quantity owing—

(1) to the differences on different days in attempting to cause the two to be co-axial;

(2) to a certain amount of looseness in the fit of the shank of the cylinder

* Nilsson, 'Science Abstracts,' vol. 6, abs. 560.

† Elster and Geitel, 'Terrestrial Mag.,' vol. 4, p. 213, *et seq.*

on to its hole. The value above given for "n" is the mean of several determinations made with different settings of the cover and cylinder. The individual values of "n" varied over about 0·03.

In reducing the observations by means of the above formula, as the relation between E and the conductivity was in any case, without knowledge of the capacity in absolute measure, one of proportionality merely, ordinary instead of Naperian logarithms were used. The voltages indicated by a given divergence of the leaves were taken from a table supplied by the makers of the instrument to Kew Observatory. The time was expressed in minutes.

In making the observations, the usual formal procedure of determining the leakage after every experiment was not adopted, as it was desired to obtain as many observations as possible in rapid succession. Thus the leakage was obtained only at fairly frequent intervals, and a curve drawn by which the ordinates of the curves representing E in the arbitrary unit explained above could be corrected.

Corresponding with the dispersion observations, observations were also made of the direction and intensity of the wind (Beaufort), the humidity, and the potential difference between a point about 10 feet above the surface of the ground and the earth. This was affected by the proximity of the building and was determined by a Kelvin portable electrometer and a water-dropper.

The leaves of the dissipation apparatus were read from a distance by the aid of a telescope, and at night the instrument was illuminated by a bull's-eye lantern attached to a pole. The lantern was only lighted during the actual minute or so that a reading was being taken.

A study of the curves so obtained led to several points of interest. In the first place it is evident that the conductivity of the air for both positive and negative electricity is very irregular, but the irregularities are such that on an average negative electricity is dispersed more rapidly than positive.

$$\text{Taking } q = \frac{\text{conductivity of air for } -\text{ve electricity}}{\text{conductivity of air for } +\text{ve electricity}},$$

six ordinary days, embracing several hundreds of observations, gave the following values for q, viz.:—

$q = 1·2$ March 1 and 2, 1903,
$= 1·2$ January 1 and 2, 1903,
$= 1·12$ January 15 and 16, 1903,
$q = 1·12$ September 1 and 2, 1902,
$= 1·27$ February 1 and 2, 1903,
$= 1·06$ December 15 and 16, 1902,

giving an average of $q = 1·16$.

Though this is so persistently as an average, yet on several occasions for

some hours together during these six days, positive electricity was dissipated the more rapidly. Thus this occurred from noon to 5.30 P.M. on January 1, and again from 6.30 to 9.30 A.M. on the morning of the next day, January 2. During these intervals there was no reversal of the sign of the atmospheric potential as indicated by the electrometer. On the first of these occasions the average value of q for the period was 0·85, and on the second 0·86. Similarly, on January 15, 1903, between 12 noon and 3.30 P.M., positive charges were dissipated the more quickly. During the interval the average value of q fell to 0·6, and the potential at the terminal of the water-dropper fell from $+50$ volts at 12.30 P.M. to -40 volts at 3 P.M., rising again at 3.45 P.M. (by which time negative electricity was again being discharged the more quickly) to $+65$ volts. On September 1, 1902, also at 5 P.M., q was for a very short time 0·4, whilst the potential of the water-dropper fell from $+90$ volts at 3·30 P.M. to -717 volts at 5 P.M., rising again to -70 volts at 6·30 P.M. From then on till noon next day, when the observations terminated, the potential remained positive, as is usually the case, but at 4.30 A.M. on September 2 the positive charge again became dissipated more quickly, and continued so till 10 A.M. During this interval q was 0·68. On February 1, 1903, positive electricity was dissipated the more quickly from 3 P.M. till 7 P.M., with no reversal of the sign of the atmospheric potential. During the interval the average value of q was 0·87. Between 6 and 6.30 P.M. on December 15, 1902, q (from a pair of observations only) became 0·8 with no reversal of atmospheric potential, whilst next morning, during very heavy rain at 6 A.M., $q = 0·7$ for a short time, with a reversal of potential sign at 5 A.M. -80 volts, and at 6.30 A.M. -180 volts. Summing up these we find:—

January 1, 1903.........	$q = 0·86$, no reversal atmospheric charge			
September 1, 1902......	$= 0·68$	"	"	"
February 1, 1903	$= 0·87$	"	"	"
December 15, 1902 ...	$= 0·8$	"	"	"
January 15, 1903	$= 0·6$, reversal atmospheric charge			
September 1, 1902......	$= 0·4$	"	"	"
December 16, 1902 ...	$= 0·7$	"	"	"

This apparently indicates that a low value for q is, as might be expected, accompanied with a reversal of sign of the atmospheric charge. On the other hand, on March 2, at 6.30 A.M., the potential became -185 volts with q about unity.

Again, considering these six days only as being more typical of ordinary

conditions than two others I shall refer to, we find there is distinct evidence of a double maximum and minimum value for the conductivity of the air for charges of both signs. Thus on the following dates the maxima and minima are well marked at the following approximate times:—

	max.	min.	max.	min.
March 1 and 2	5 P.M.	9 P.M.	3 A.M.	7 A.M.
January 1 and 2.........	12 noon	6 P.M.	3 A.M.	7 A.M.
January 15 and 16......	12 noon	6 P.M.	3 A.M.	9 A.M.
September 1 and 2......	2 P.M.	5 P.M.	1 A.M.	9 A.M.

Of the two other days, viz., February 1 and 2 and December 15 and 16, the former exhibits no distinct maxima and minima, but a strong south-west gale was blowing during most of the period of observation; and the latter is incomplete in the night hours owing to faulty insulation of the instrument due to rain. The four days above were fine.

The observations made on February 1 and 2 during the south-west gale gave a much higher value for the conductivity of the air for both positive and negative charges than upon the other four complete days. Thus, in the arbitrary units chosen, the mean conductivity for this day was for positive charge 0·00694 and for negative 0·00880, whilst the average of the other four was for positive 0·00330 and for negative 0·00375. Similarly, on March 1 and 2, also during a south-west wind of moderate strength, the conductivities were higher than the average, viz., for positive charges 0·00475 and for negative 0·00569. Since the wind on these two days of high mean conductivity was in the same direction, south-west, and also stronger than on the other three, there is only a slight amount of evidence to indicate that the excessive conductivity is due to the strength rather than to the direction of the wind.

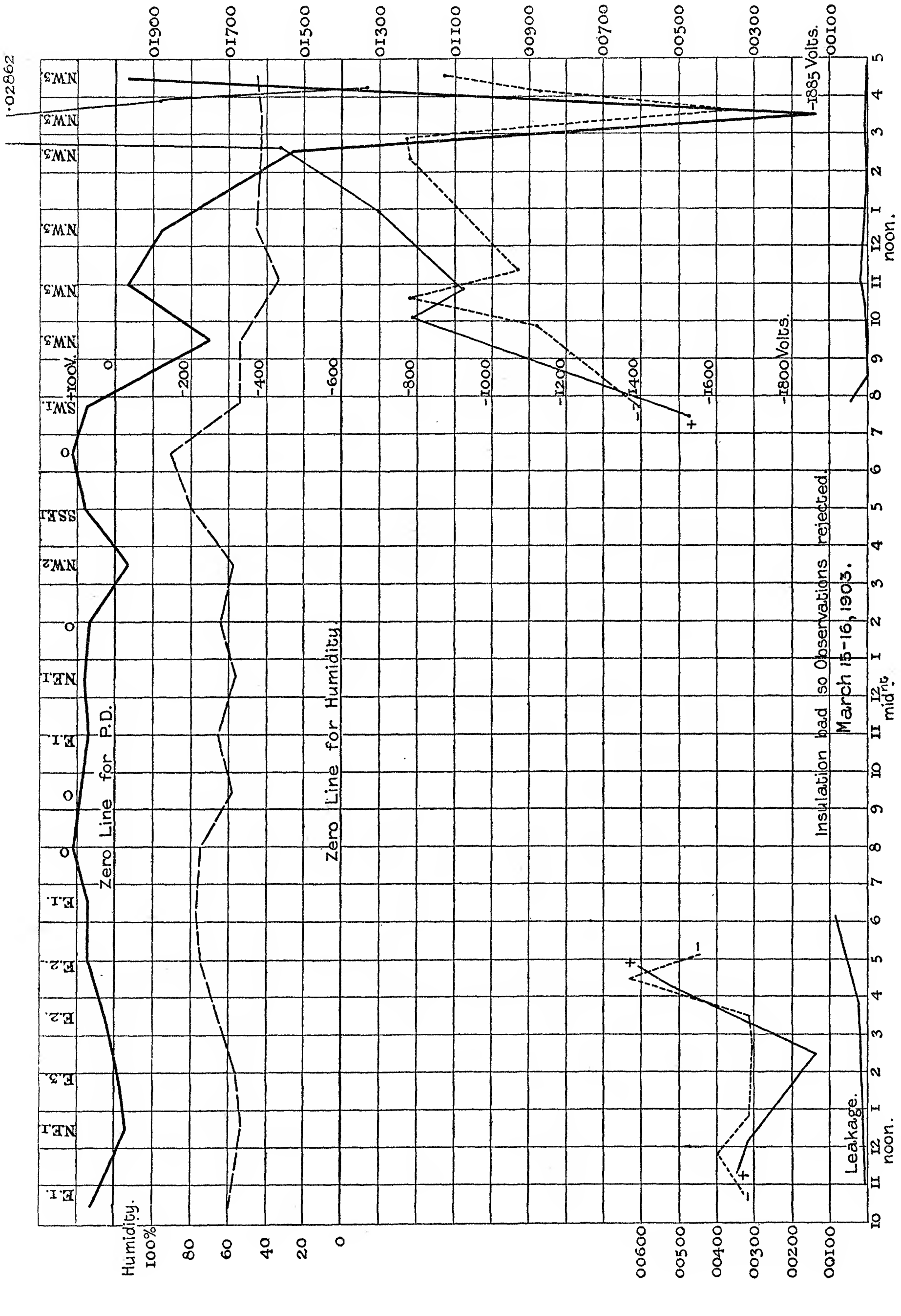
I am unable to discover in these curves any connection between the humidity of the air and its electrical condition.

I now come to two days as yet not mentioned, viz., February 18, on which observations were specially made from 11 A.M. to 5 P.M., and March 16, when observing conditions were good from 7 A.M. till 5 P.M. On the first of these two days a strong gale from the north-west—a "nor'wester" as they are generally called here—was blowing at the time the observations were begun, whilst on the latter, at 6.30 A.M., the wind was calm. At 8 A.M. there was a light south-west wind, and at 9.30 it was blowing strongly from the north-west with a characteristic falling barometer. The wind remained north-west during the rest of the day. These "nor'westers" are very well known and,

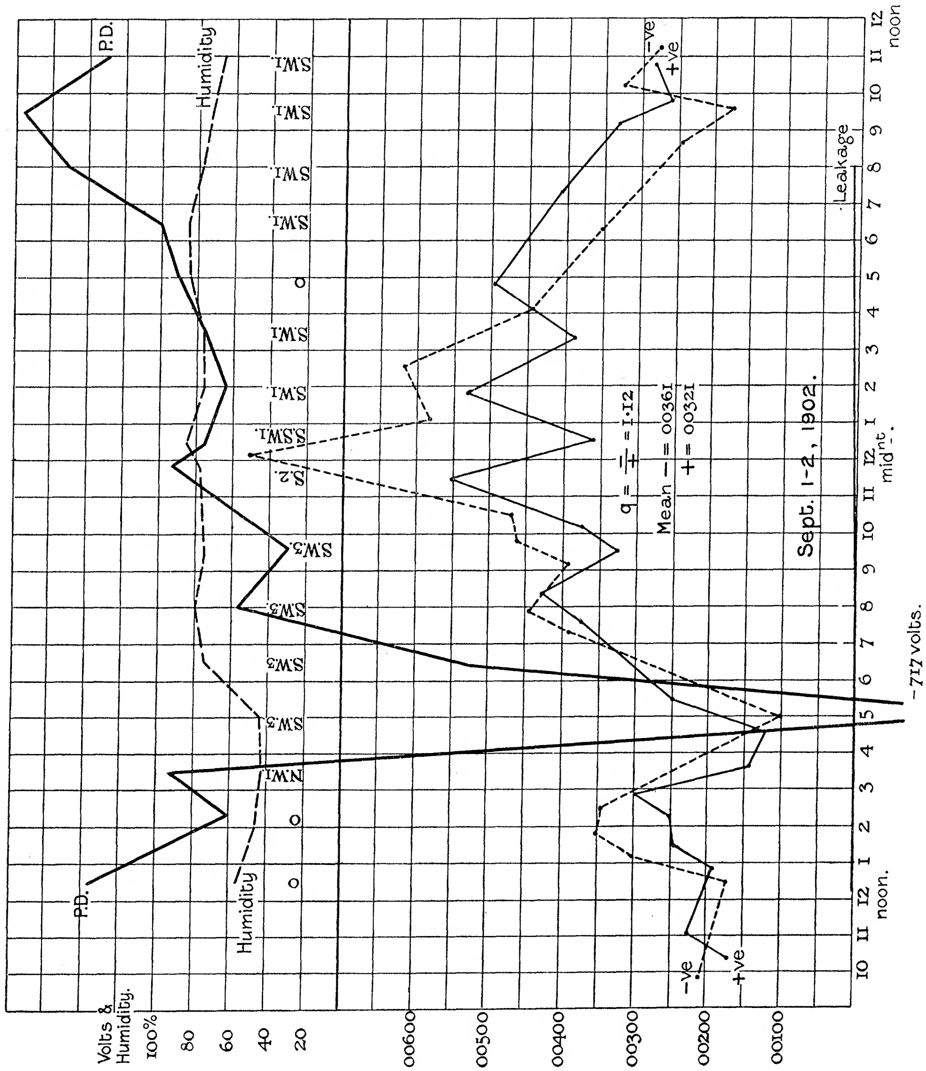
by some people, rather dreaded winds. Blowing over a high range of mountains reaching 7000 feet, they deposit their moisture on the western slopes, though the rain often extends to the eastern side of the mountains. In Christchurch, and for some distance westward of it, these winds are invariably dry and hot. They are of the nature of "Foehn" winds, and have a very depressing effect upon most people, though I have met some who say they like them.

Though the days I am describing are the only two of the class upon which, so far, I have been able to take dissipation observations, yet potential observations on them indicate that the general character of these winds is that they are negatively charged relatively to the earth, which is contrary to the usual condition. On both of these days the dissipation curves show marked peculiarities. The earliest observation, at 11.15 A.M. on February 18, gave $q = 0{\cdot}4$ with a negative potential difference between water-dropper and earth of, -300 volts at 10.20 A.M., -150 volts at 11.40 A.M., and -50 volts at 12.45 P.M. These three values at the times indicated lie on a straight line and appear to show that the potential of the water-dropper was rising approximately uniformly with the time. Corresponding with this rise of potential there is also a marked rise in the value of q, which at 12 noon had risen to $0{\cdot}8$ and at 2.30 P.M. was $1{\cdot}5$, by which time the "nor'wester" had practically blown itself out, and the potential of the water-dropper was zero. After this the value of q sank again to approximately unity, the ordinary positive atmospheric charge established itself and the wind blew lightly from the south-west.

The curves corresponding to March 16 (see the figure) are of a precisely similar character, but here the whole history of the wind is apparent. At 7.30 A.M. the wind was light south-west, $q = 1{\cdot}3$, potential of water-dropper $+90$ volts. At 9.45 A.M., wind north-west, strong, $q = 0{\cdot}7$, potential -250 volts. At 10.30 A.M., wind north-west, strong, $q = 1{\cdot}1$, potential -100 volts approximately (interpolated). From this hour the north-west wind seemed to have thoroughly established itself. The values of q became less and less, the curves indicating the conductivity of the air for positive and for negative charges diverging rapidly, that for positive reaching a high value whilst the negative curve reached remarkably low values. Thus at about 3 P.M., the point of maximum divergence of these curves, in the arbitrary units chosen for the conductivities, that for positive electricity was $0{\cdot}029$, whilst the conductivity for negative electricity was only $0{\cdot}0037$, giving a value for q of $0{\cdot}12$. Corresponding with this extremely low value for q the potential reached at very approximately the same time its greatest negative value, viz., -1885 volts. After this the value of q increased, the curves representing the


March 15-16, 1903.
Insulation bad so Observations rejected.
Zero Line for P.D.
Zero Line for Humidity
Leakage.
Humidity. 100%
-1885 Volts.
-1800 Volts.
+100 V.

conductivities converging—that for positive electricity coming down whilst the negative conductivity increased. Corresponding with this increase of q the negative potential of the water-dropper decreased, until at 4.30 P.M.



$q = 0{\cdot}94$, potential -30 volts, wind still strong from north-west; but it dropped shortly after this.

It may be possible to account for the peculiar character of these two north-west winds (and though I have so far been unable to obtain further observations, I expect to find it common to the wind) in this way. The wind,

as stated, blows over a mountain range. These mountains may rob the air of positive ions owing to the denser negative charge on the peaks.* Thus the air may come over the Canterbury Plains with an excess of negative ions, giving it great conductivity for positive charges and conferring on it its own characteristic highly negative charge.

In the curves reproduced the lowest line of all represents the actual leakage, the faint dotted line the variations in conductivity for negative charges, and the faint full line those for positive charges. These are all in the same arbitrary units explained above. The heavy full line represents the variations in the potential of the water-dropper referred to an origin higher up in the paper. The broken line represents the relative humidity. The letters E., N.E., etc., denote the direction of the wind, and the attached numerals its intensity on Beaufort's scale.

My thanks are due to Mr. H. F. Skey, B.Sc., for aid in making the observations on September 1, and to Mr. F. Sandford for help on January 15, February 1 and 18, and March 1 and 15. For the opinions expressed, and for the observations on December 15 and January 1, I alone am responsible, as I am also for the accuracy of the reductions.

* See also Elster and Geitel's results at Wolfenbüttel.